University of South Bohemia

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Application of modern data analysis tools in small mammal systematics

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Annotation

The present PhD thesis comprised of one review and three research papers dealing with application of modern data analysis tools, concretely geometric morphometrics and modern regression, in small mammal systematics.

Poděkování

Prohlašuji, že svoji disertační práci jsem vypracovala samostatně pouze s použitím pramenů a literatury uvedených v seznamu citované literatury.

Prohlašuji, že v souladu s § 47b zákona č. 111/1998 Sb. v platném znění souhlasím se zveřejněním své disertační práce, a to v úpravě vzniklé vypuštěním vyznačených částí archivovaných Přírodovědeckou fakultou, elektronickou cestou ve veřejně přístupné části databáze STAG provozované Jihočeskou univerzitou v Českých Budějovicích na jejích internetových stránkách.

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Stanovisko spoluautorů:

Prohlašuji, že se Lenka Barčiová převažující měrou podílela na vzniku následující vědecké práce/prací:

➤ Landmark-based analysis of the cranial variation in the silvery mole rat, *Heliophobius argenteocinereus* (Rodentia, Bathyergidae)

      Mgr. Radim Šumbera, PhD.   prof. RNDr. Hynek Burda, CSc.

➤ Morphometric study of two species of wood mice, *Apodemus sylvaticus* and *A. flavicollis* (Rodentia: Muridae) from the Czech Republic: traditional and geometric morphometric approach

➤ Morphometric key for the discrimination of two wood mice species, *Apodemus sylvaticus* and *A. flavicollis*

      doc. RNDr. Miloš Macholán, CSc.

1. Synopsis

Morphometrics, the study of the variation and change in form among organisms, serves as a basic methodological tool in various fields of biological research, among others in the field of systematics. During the last fifteen years, morphometrics has seen the rapid development of a modern methodological approach called "geometric morphometrics" (Rohlf & Marcus 1993; Adams et al. 2004; Slice 2005), especially of the methods that use the coordinates of points (landmarks or semi-landmarks) as data. The recent important developments in the field include the extension of interesting multivariate methods to landmark data, such as partial least squares (see Rohlf and Corti 2000) or path analysis (Caumul & Polly 2005), and new approaches to the phylogenetic analysis of shape (e.g. MacLeod & Forey 2002, Caumul & Polly 2005). In Chapter 2, landmark-based methods are briefly described and their applications in systematics of small mammals (belonging to families Eulipotyphla and Rodentia) are summarized.

In Chapter 3, cranial variation was explored in the silvery mole rat (*Heliophobius argenteocinereus*) and the effects of geographic position and environmental conditions on skull shape and size differences among studied populations were evaluated using landmark-based morphometric approach.

In Chapter 4, skull shape and size were investigated in *Apodemus sylvaticus* and *A. flavicollis* using traditional and geometric morphometric approach in order to find potential diagnostic morphometric criteria, which would allow discrimination between individuals of these two morphologically similar species, to analyze interpopulation variation in both species and simultaneously evaluate the effect of the presence/absence of the congener at the same site.

The last manuscript (Chapter 5) focused on the establishment of a simple identification key diagnosing two *Apodemus* species using classification tree, i.e. the tree-based type of modern regression models (see e.g. Lepš & Šmilauer 2003). This technique tends to be more often applied in mammalian ecology (e.g. Smith et al. 1997, Ecke et al. 2006, Swihart et al. 2007) but has been rather neglected in studies dealing with discrimination between morphologically similar mammal species. Karels et al. (2004) evaluated the predictive power of discriminant function analyses (DFA) and classification tree method for discrimination of age classes in two marmot species and concluded that neither method appeared to outperform

the other but classification tree technique is more effective for analysis of incomplete data sets due to its ability to deal with missing values. To further advantages of classification tree technique over DFA belong the consideration of the non-additive interactions among explanatory variables and no assumption of any specific distribution of the data.

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2. Advances in insectivore and rodent systematics due to geometric morphometrics

by Lenka Barčiová

Submitted to Mammal Review

Abstract

Morphometrics, the study of the variation and change in form among organisms, serves as a basic methodological tool in various fields of biological research, including the field of systematics. Due to additional information about spatial relationships among anatomical landmarks, geometric morphometrics is more suitable for analyzing morphometric variation than those methods based on distance measurements and allows us to answer general ecological and evolutionary questions about shape. In this paper, landmark-based methods are briefly described and illustrated, based on a dataset of 295 wood mice mandibles, and then the applications of such methods in the systematics of insectivores (Eulipotyphla) and rodents (Rodentia) are summarized.

3. Landmark-based analysis of the cranial variation in the silvery mole rat, *Heliophobius argenteocinereus* (Rodentia, Bathyergidae)

by Lenka Barčiová, Radim Šumbera and Hynek Burda
Manuscript, unpublished

Abstract

We investigated the cranial variation in subterranean silvery mole-rat, *Heliophobius argenteocinereus* (Bathyergidae, Rodentia) using geometric morphometric approach and evaluated the effect of ecogeographical factors on size and shape differences among four populations. Altogether, 69 specimens from one Zambian and three Malawian sites were studied. No evidence for sexual dimorphism was found in the skull size or shape. The skull size differed only between the Zambian and Malawian populations. The cranial shape variation was large, and influenced mainly by the latitudinal gradient and the type of habitat (pristine miombo woodland versus farmland and grassland), whereas the allometric growth accounted only for 17.6% and 21.4% of the total variation in the dorsal and ventral view respectively.

Key words

Heliophobius, skull, geometric morphometrics, functional morphology, subterranean rodent

4. Morphometric study of two species of wood mice, *Apodemus sylvaticus* and *A. flavicollis* (Rodentia: Muridae) from the Czech Republic: traditional and geometric morphometric approach

by Lenka Barčiová and Miloš Macholán

Abstract

Skull shape and size were investigated in 311 specimens of *Apodemus sylvaticus* (Linnaeus, 1758) and *A. flavicollis* (Melchior, 1834), using traditional and geometric morphometric approach. We searched for potential morphometric diagnostic criteria between these morphologically similar mice and we analyzed the interpopulation morphometric variation. Specific status of all individuals was identified by scoring four diagnostic allozyme markers. Discriminant analysis based on 16 cranial measurements as well as that based on landmark data for ventral side of the skull discriminated individuals with 99.7% accuracy. The classification functions useful for practical discrimination of unknown specimens are given. Our data showed neither clear intraspecific geographical pattern among studied populations nor evidence for character displacement in syntopic populations of *A. sylvaticus* and *A. flavicollis.*

5. Morphometric key for the discrimination of two wood mice species, *Apodemus sylvaticus* and *A. flavicollis*

by Lenka Barčiová and Miloš Macholán

Abstract

Sixteen cranial measurements were examined in 311 genetically identified specimens of *Apodemus sylvaticus* and *A. flavicollis* in order to establish a simple identification key diagnosing these two morphologically similar species using the classification tree technique. The resulting identification key includes three cranial measurements only (length of the lower tooth row, condylobasal length, length of *bulla tympanica*) and enables separation of the species under investigation with 98.3% accuracy. Moreover, some previously proposed identification criteria for *A. sylvaticus* and *A. flavicollis* are reviewed and their applicability is discussed.

Key words

Apodemus, discrimination, classification trees

6. Conclusion

The present PhD thesis comprised of four manuscripts dealing with application of modern data analysis tools, concretely geometric morphometrics and modern regression, in small mammal systematics. The conclusions of individual papers follow:

1) Advances in insectivore and rodent systematics due to geometric morphometrics

The geometric morphometric approach was described and their applications in insectivore and rodent systematics were reviewed. Landmark-based methods are an effective tool for analyzing sexual dimorphism, geographic variation and evolutionary processes in closely related taxa. Otherwise it has been shown that landmark data contains detectable phylogenetic signal, but it remains questionable to what extent the phylogeny can be recovered from them.

2) Landmark-based analysis of the cranial variation in the silvery mole rat, *Heliophobius argenteocinereus* (Rodentia, Bathyergidae)

We investigated the cranial variation in 69 silvery mole rats (*Heliophobius argenteocinereus*) coming from one Zambian and three Malawian sites. The skull size did not differ among localities and geographic longitude was the only ecogeographic variable significantly associated with skull size. No evidence for sexual dimorphism was found in the skull size or shape. The allometric growth accounted for 17.6% and 21.4% of the cranial shape variation in the dorsal and ventral view respectively. The latitudinal gradient and the type of habitat seemed to be the main ecogeographical factors influencing the shape variation in *Heliophobius.*

3) Morphometric study of two species of wood mice, *Apodemus sylvaticus* and *A. flavicollis* (Rodentia: Muridae) from the Czech Republic: traditional and geometric morphometric approach

Skull shape and size were investigated in 311 genetically identified specimens of *Apodemus sylvaticus* and *A. flavicollis,* using traditional and geometric morphometric approach. The canonical discriminant function defined for distance measurements as well as for the overall shape of the ventral side separated the species under study with 99.7% accuracy. Our data

showed neither clear intraspecific geographical pattern among studied populations nor evidence for character displacement in syntopic populations of *A. sylvaticus* and *A. flavicollis.*

4) Morphometric key for the discrimination of two wood mice species, *Apodemus sylvaticus* and *A. flavicollis*

Sixteen cranial measurements were examined in 311 genetically identified specimens of *Apodemus sylvaticus* and *A. flavicollis* in order to establish a simple identification key diagnosing these morphologically similar species using the classification tree technique. The resulting identification key includes three cranial measurements only (length of the lower tooth row, condylobasal length, length of *bulla tympanica*) and enables to separate the species under study with 98.3% accuracy.